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UNITED STATES GOVERNMENT
# memorandum

DATE: September 15, 1992

REPLY TO ATTN OF: Supervisor, New Jersey Field Office, Fish and Wildlife Enhancement
Pleasantville, New Jersey

SUBJECT: Supawna Meadows National Wildlife Refuge Follow-up Contaminant Investigation

TO: Assistant Regional Director, Refuges and Wildlife
Newton Corner, Massachusetts

Through: Assistant Regional Director, Fish and Wildlife Enhancement
(Attn: Arnold Julin)

This memorandum serves to document transmittal of the technical assistance report entitled, "Environmental Contaminants Investigation of Supawna Meadows National Wildlife Refuge: Contamination and Toxicity of Mud Creek Sediments and Heavy Metal Characterization of the Refuge Impoundment." The study was designed to further investigate concerns evidenced as a result of our 1989 refuge-wide investigation. Specifically, the subject document addresses the extent of lead and zinc contamination in the refuge impoundment, the extent of heavy metal and PCB pollutant loading at the Killcohook dredge material disposal site outfall (Mud Creek), and the toxicity of sediments in Mud Creek. The original analytical methodology and chemistry reports, including quality assurance statements will remain on file at the New Jersey Field Office and are available upon request.

If you have any questions regarding this memo or the subject report, please contact Mark Roberts of my staff (609-646-9310).

Clifford G. Day

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TECHNICAL ASSISTANCE REPORT

# ENVIRONMENTAL CONTAMINANTS INVESTIGATION OF SUPAWNA MEADOWS NATIONAL WILDLIFE REFUGE:

## CONTAMINATION AND TOXICITY OF MUD CREEK SEDIMENTS AND HEAVY METAL CHARACTERIZATION OF THE REFUGE IMPOUNDMENT

Department of the Interior
U.S. Fish and Wildlife Service

September 1992

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# ENVIRONMENTAL CONTAMINANTS INVESTIGATION OF SUPAWNA MEADOWS NATIONAL WILDLIFE REFUGE:

## CONTAMINATION AND TOXICITY OF MUD CREEK SEDIMENTS AND HEAVY METAL CHARACTERIZATION OF THE REFUGE IMPOUNDMENT

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September 1992

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# PREFACE

The information presented in this technical assistance report documents the 1991 environmental contaminants evaluation of sediments and surface water from Supawna Meadows National Wildlife Refuge, Salem County, New Jersey. The study was designed to further investigate concerns evidenced as a result of the 1989 refuge-wide investigation (U.S. Fish and Wildlife Service, 1991).

This contaminants evaluation represents cooperative monitoring of the refuge by the U.S. Fish and Wildlife Service's activities of Fish and Wildlife Enhancement, and Refuges and Wildlife in Region 5. Study design, implementation, data analyses, and reporting were completed by Environmental Contaminants personnel in the New Jersey Field Office (Fish and Wildlife Enhancement). Funding for the project and assistance with sample collection were provided by Refuges and Wildlife.

Questions, comments, and suggestions related to this report are encouraged and should be submitted in writing to the following address:

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927 North Main Street (Building D-1)
Pleasantville, New Jersey 08232

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## ACKNOWLEDGEMENTS

This monitoring effort was designed, coordinated and conducted by Tom Augspurger, a Fish and Wildlife Service Biologist formerly with the New Jersey Field Office and currently with the Service's Raleigh, North Carolina Field Office. Assistance with sample collection was provided by the previous Supawna Meadows National Wildlife Refuge Manager, Richard Guadagno. Dr. Marcia Nelson of the Service's National Fisheries Contaminant Research Center in Columbia, Missouri provided invaluable technical assistance during planning and in conducting bioassays.

# INTRODUCTION

Supawna Meadows National Wildlife Refuge (Figure 1) consists of approximately 890 hectares of estuarine emergent wetlands and uplands along the Delaware and Salem Rivers in Salem County, New Jersey. The refuge provides important habitat for a variety of migratory waterfowl and wading birds, including American black duck (_Anas rubripes_), Northern pintail (_Anas acuta_), Canada goose (_Branta canadensis_), great blue heron (_Ardea herodias_), little blue heron (_Egretta caerulea_), glossy ibis (_Plegadis falcinellus_), great egret (_Casmerodius albus_), and double-crested comorant (_Phalacrocorax auritus_), and numerous species of shorebirds (U.S. Fish and Wildlife Service, 1989).

A 1989 environmental contaminants investigation (U.S. Fish and Wildlife Service, 1991) of the refuge revealed that zinc (59 to 2,980 ppm dry weight) was elevated throughout refuge sediments with the highest value detected in the refuge impoundment (Figure 2). The 2,980 ppm dry weight of zinc in the single impoundment sample is more than an order of magnitude higher than the refuge average. The highest sediment lead level (139 ppm dry weight) was also determined at this location. The history of waterfowl hunting in this area points to lead shot as the likely source of this contamination (U.S. Fish and Wildlife Service, 1989). Lead poisoning of waterfowl from ingestion of lead shot has been documented in the region (Roscoe et al., 1989), and because the lead and zinc levels in impoundment sediments were determined by only one sample, additional testing was deemed necessary to better characterize the extent of heavy metal contamination.

The background environmental contaminants survey also suggests that the sediments of Mud Creek are of concern. Mud Creek receives effluent from the Killcohook dredge material disposal outfall via six 24-inch corrugated steel pipes crossing under Ft. Mott Road (Figure 2). The highest sediment and mummichog (_Fundulus heteroclitus_) tissue PCB levels (0.45 ppm wet weight and 0.20 ppm dry weight, respectively) and the highest mummichog tissue concentrations of aluminum, cadmium, chromium, iron, nickel, and lead were detected at two sample locations in Mud Creek. The sediment PCB concentration at one location exceeded screening values for toxicological effects as well as regional average sediment PCB levels of 1980-81 (Hochreiter, 1982).

This study was designed with three objectives aimed at furthering the understanding of contaminants at the refuge impoundment and Mud Creek:

1) determine the extent of lead and zinc contamination in the refuge impoundment;

2) characterize the extent of heavy metal, PAH, and PCB pollution loading at the Killcohook dredge material disposal site outfall (Mud Creek); and,

3) assess the toxicity of downgradient sediments in Mud Creek including samples collected adjacent to a minor dump site on the Freas property.

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Figure 1. Supawna Meadows National Wildlife Refuge, Salem County, New Jersey.

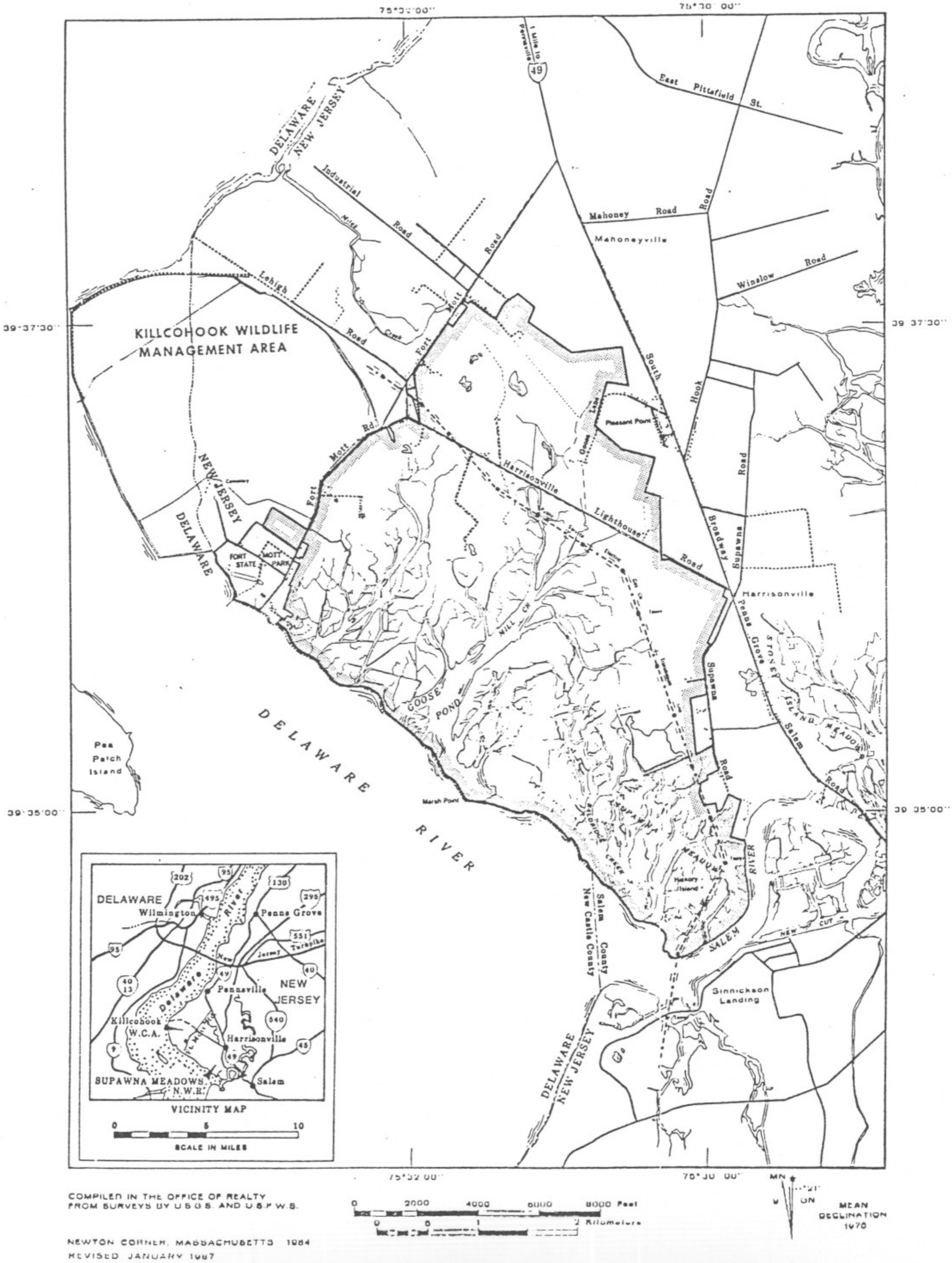
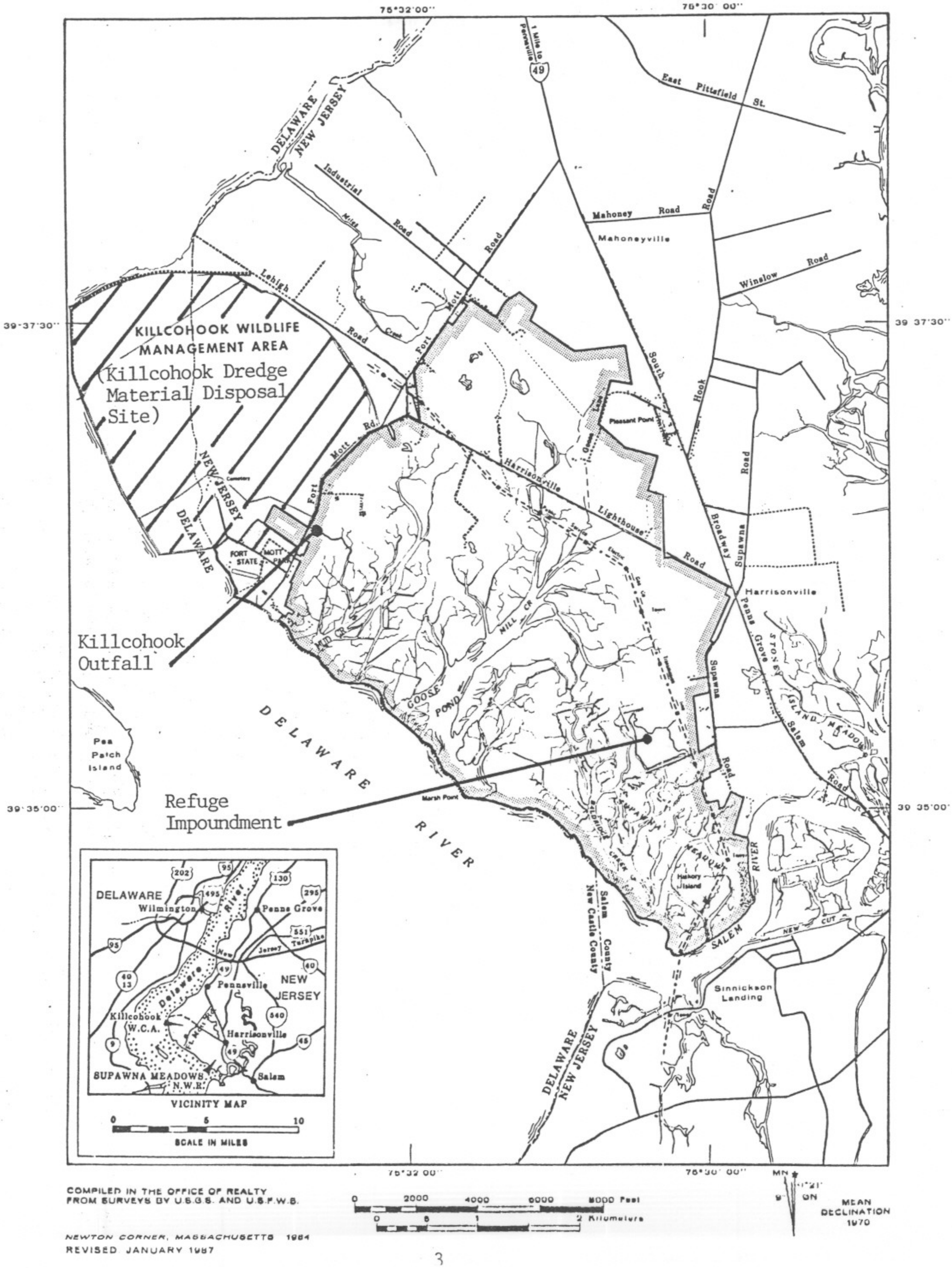


Figure 2. Refuge Impoundment and Killcohook Outfall, Supawna Meadows National Wildlife Refuge, Salem County, New Jersey.



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## METHODS

### Study Design and Sampling Scheme

Five composite sediment samples (via stainless steel petite ponar dredge) were collected from Mud Creek in a transect from the Killcohook outfall between June 27-28, 1991. Two additional sediment samples were collected on June 28, 1991, in a drainage from a minor dump site approximately 1,500 meters and downgradient from the Killcohook outfall (Figure 3).

Five composite sediment samples (via stainless steel mud auger) and three surface water samples (via grab) were collected from the refuge impoundment on July 24, 1991. In addition, sediment and surface water were collected from a reference site adjacent to Hickory Island in Goose Creek (Figure 4). This site was previously shown to have among the lowest concentrations of PAHs, organochlorines, and heavy metals in an earlier investigation (U.S. Fish and Wildlife Service, 1991).

A decontamination procedure, consisting of an ambient water rinse, scrubbing with a non-phosphate detergent, distilled water rinse, 10 percent nitric acid rinse, another distilled water rinse, acetone rinse, and a final extensive distilled water rinse, was completed for all sample equipment between sample stations. Samples were stored in pre-cleansed glass containers purchased with teflon cap liners from I-Chem Research. All samples were immediately placed in coolers with wet ice. Upon returning from the field, the samples were stored in a refrigerator at 4° centigrade until set-up of bioassays or shipment to analytical laboratories. Holding times for sediments used for bioassay work and those shipped to analytical facilities were approximately 20 and 50 days, respectively.

Samples from the refuge impoundment were only analyzed for elemental contaminants (Table 1) as lead and zinc were analytes of concern from earlier work. A combination of bioassay techniques and residue chemistry was employed for the samples collected from Mud Creek. The MICROTOX bioassay was used to screen collected sediments and surface waters for toxicity; this screening was intended to limit the extent of samples submitted for residue chemistry or longer duration bioassays. Sediments were screened by MICROTOX using pore water extracted from sediments according to the hand held vacuum pump method of Winger and Lasier (1991). The MICROTOX test system measures the light generated by luminescent bacteria after they have been rehydrated and exposed to a pore water sample, and compares the light output to that of a control (reagent blank). The degree of light loss (which measures metabolic inhibition in the test organisms) indicates the degree of toxicity of the sample. The 100 percent assay procedure, as outlined by Microbics Corporation (1991), was followed, as it represents the most appropriate assay for samples of unknown toxicity.

Since all Mud Creek sediment porewaters exhibited MICROTOX response (discussed later), sediments were subsequently analyzed for elemental contaminants (Table

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Figure 3. Sample Collection Sites for the 1991 Mud Creek Follow-up Contaminants Survey, Supawna Meadows National Wildlife Refuge, Salem County, New Jersey.

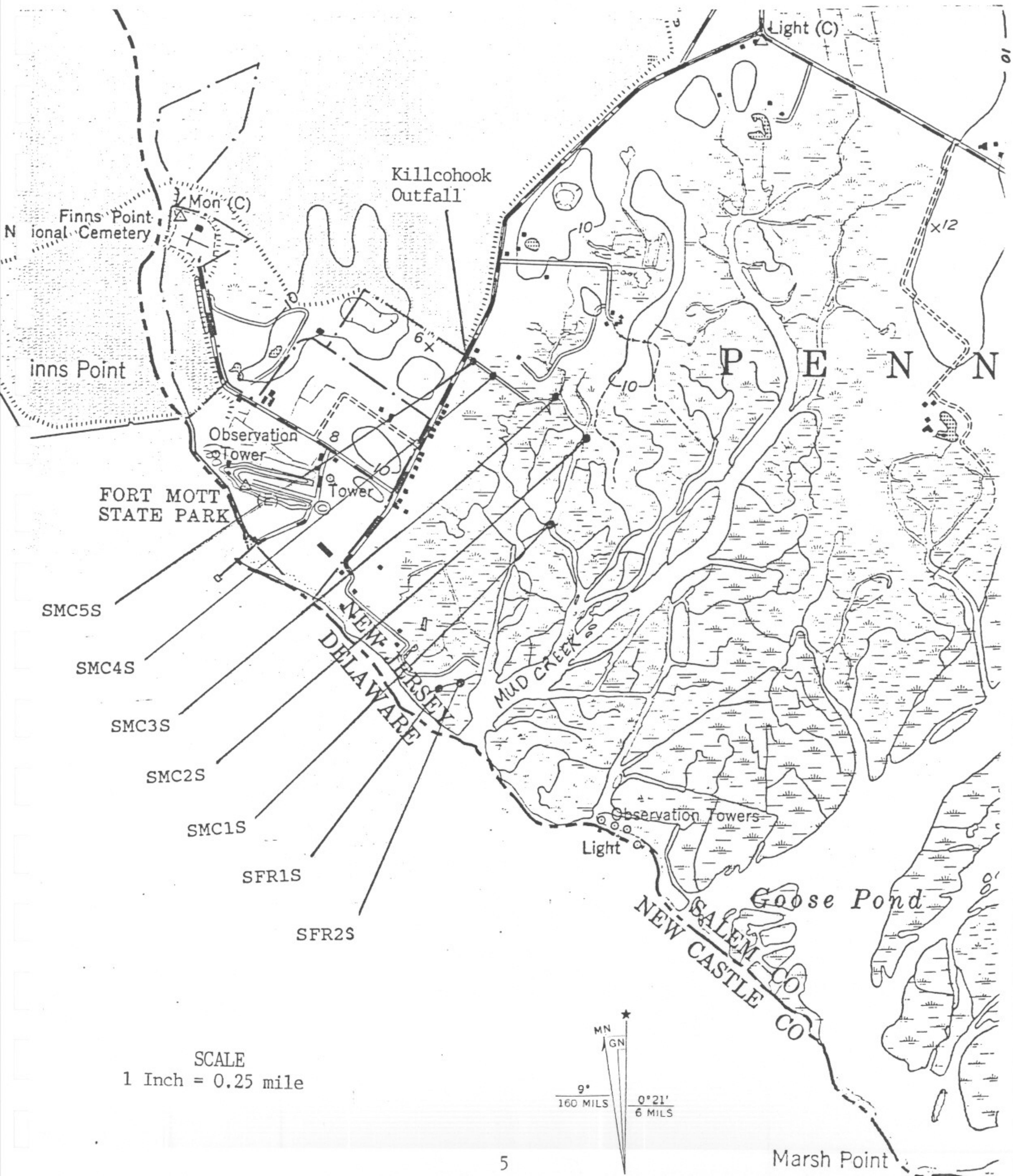

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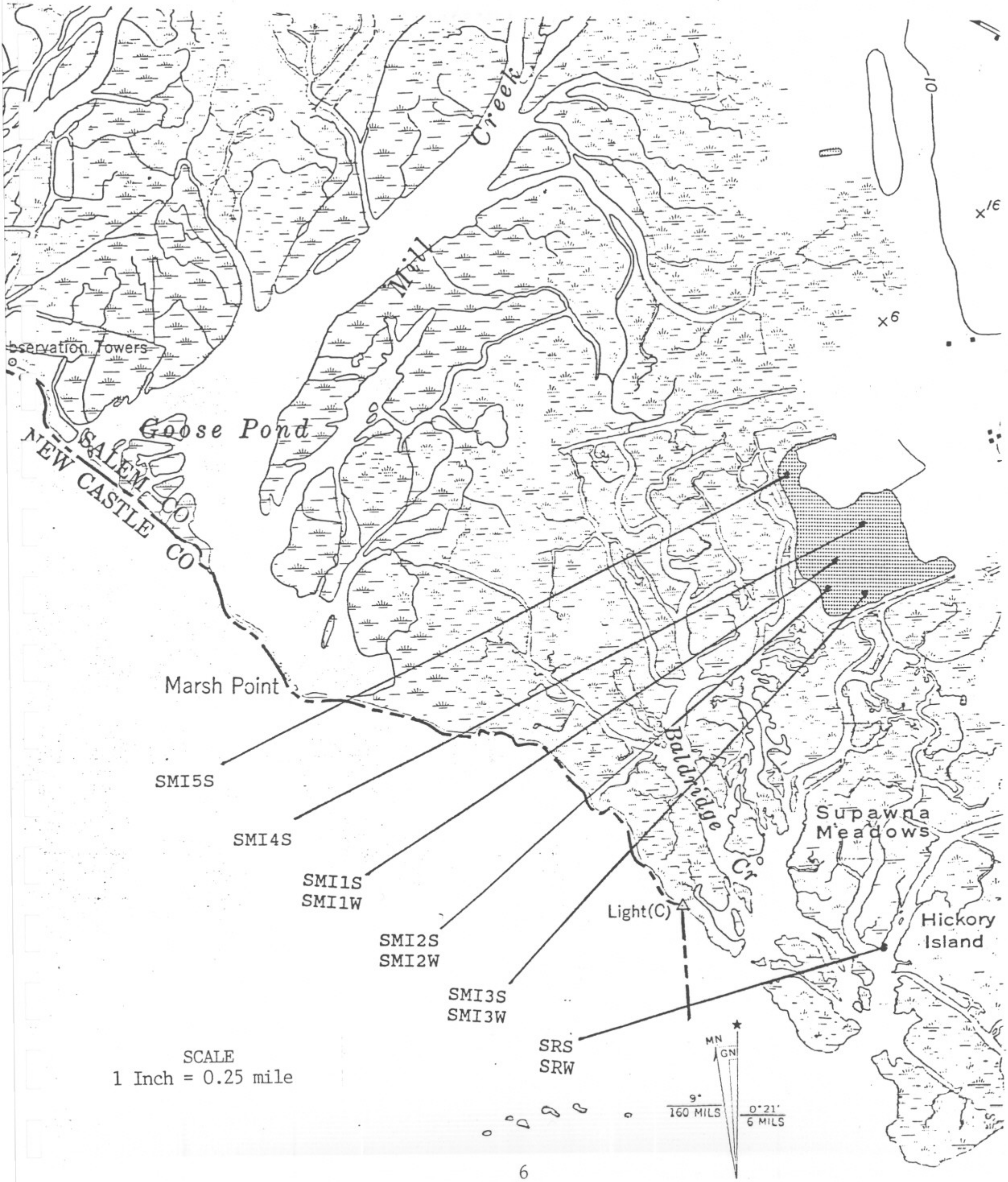
Figure 4. Sample Collection Sites for the 1991 Refuge Impoundment Follow-up Contaminants Survey, Supawna Meadows National Wildlife Refuge, Salem County, New Jersey.




SCALE
1 Inch = 0.25 mile

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Table 1. Elemental Contaminants and Method Detection Limits

| | |
|---|---|
| Aluminum | Mercury |
| Arsenic | Magnesium |
| Barium | Manganese |
| Beryllium | Molybdenum |
| Boron | Nickel |
| Cadmium | Selenium |
| Chromium | Strontium |
| Copper | Vanadium |
| Iron | Zinc |
| Lead | |

Lower level of detection for sediments = 0.01 ppm
Lower level of detection for surface water = 0.0005 ppm.

Table 2. Organochlorine Analytes and Method Detection Limits.

| | |
|---|---|
| HCB | total PCB's |
| a-BHC | dieldrin |
| b-BHC | endrin |
| r-BHC | mirex |
| g-BHC | o,p'-DDE |
| heptachlor epoxide | p,p'-DDE |
| oxychlordane | o,p'-DDD |
| a-chlordane | p,p'-DDD |
| r-chlordane | o,p'-DDT |
| trans-nonachlor | p,p'-DDT |
| cis-nonachlor | toxaphene |

Lower level of detection for sediments = 0.01 ppm (except for toxaphene and PCB's which is = 0.05 ppm).

Table 3. Polycyclic Aromatic Hydrocarbons and Method Detection Limits.

| | |
|---|---|
| naphthalene | chrysene |
| fluorene | benzo(b)fluoranthrene |
| phenanthrene | benzo(k)fluoranthrene |
| anthracene | benzo(e)pyrene |
| fluoranthrene | benzo(a)pyrene |
| pyrene | 1,2,5,6-dibenzanthracene |
| 1,2-benzanthracene | benzo(g,h,i)perylene |

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1), organochlorines (Table 2), and PAHs (Table 3). Additionally, sediments from Mud Creek were used in a bulk sediment 14 day bioassay with the amphipod Hyalella azteca as described in Ingersoll and Nelson (1990). Three replicates of 20 amphipods each were used for the 5 test sediments, reference site sediment, and a negative control (sterile gauze substrate). A negative control was used to determine if laboratory test conditions were satisfactory as mortality greater than 20 percent in any negative control replicate would deem the experiment unacceptable (Nelson et al., 1991). Mean survival in test sediments were compared to mean survival in the reference site sediments via one-way analysis of variance. A 95 percent confidence level was selected to determine statistical significance.

## Analytical Methods

Analyses for organochlorines, and PAHs were performed at Mississippi State Chemical Laboratory, Mississippi State, Mississippi. The inorganics, total organic carbon (TOC), and grain size analyses were conducted by Research Triangle Institute, Research Triangle Park, North Carolina. All sediments were analyzed for TOC and grain size to aid in data interpretation.

Sediments and surface waters in the impoundment were analyzed for metals by inductively coupled argon plasma emission (ICP). In addition, mercury and arsenic content were determined by graphite furnace atomic absorption (GFAA).

Sediments from Mud Creek were analyzed for organochlorine pesticides and PCBs by electron capture capillary gas chromatography (GC), and for polycyclic aromatic hydrocarbons by capillary GC with a flame ionization detector. Sediments and surface waters from this location were analyzed for most metals by ICP; mercury and arsenic were by GFAA.

## Comparative Criteria

MICROTOX results were compared to subjective criteria established by Henry and Jaschke (1992). Based on three years experience in interpreting MICROTOX results, the researchers provided the following 5 or 15 minute MICROTOX $EC_{50}$ criteria:

| | |
|---|---|
| 0 - 19 | Extremely Toxic |
| 20 - 39 | Very Toxic |
| 40 - 59 | Toxic |
| 60 - 79 | Moderately Toxic |
| 80 - 99 | Slightly Toxic |
| > 100 | Non-toxic |

Metal concentrations in sediment samples were compared to the New Jersey Department of Environmental Protection and Energy's (NJDEPE) Interim Soil Action Levels (ISALs). These concentration effects values represent levels at which further characterization of contamination (vertical and horizontal) is recommended. Specific clean-up levels are judged on a case by case basis, but may be the ISAL level (New Jersey Department of Environmental Protection and

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Energy, 1990). A further comparison was made to the U.S. Environmental Protection Agency's (USEPA) 1977 descriptive criteria for Great Lakes Harbor sediment (U.S. Environmental Protection Agency, 1977), USEPA's Puget Sound Apparent Effects Thresholds (AETs) (U.S. Environmental Protection Agency, 1988), and the National Oceanic and Atmospheric Administration (NOAA) environmental effects values (Long and Morgan, 1991). The NOAA environmental effects values were used by that agency to assess the potential biological effects of contaminated sediments as part of their national monitoring program, and are not to be considered criteria for clean-up. The NOAA defines the lower 10 percentile in the data as the Effects Range-Low (ER-L) and the median concentration showing effects as the Effects Range-Median (ER-M). The ER-M values for each contaminant represents the concentration above which effects were frequently observed or predicted among most species.

Sediment PAH values were compared to the NJDEPE ISAL of 10 ppm for base neutrals, NOAA's ER-L of 4 ppm, and Chapman et al. (1987) which reports marine sediment quality criteria for PAHs ranging from 2-12 ppm. Sediment DDT (total) and PCB (total) levels were compared to the NJDEPE ISAL of 1 ppm for residential areas.

Metal parameters in surface water were compared to the most sensitive of USEPA's Water Quality Criterion (U.S. Environmental Protection Agency, 1986).

## RESULTS

## MUD CREEK

### Microtox

Five minute $EC_{50}$ MICROTOX results and corresponding toxic criteria are presented in Table 4. Response ranged from extremely to slightly toxic for Mud Creek sediments, with no apparent gradient-related trend. The reference site sediments were characterized as non-toxic.

### Bioassay

Mean survival of *Hyalella azteca* used in the bioassay test ranged from 80 - 100 percent and no statistically significant differences were found among sediments sampled in Mud Creek and the reference site (Table 5).

### Sediments

The previous detection of low level PCB contamination in Mud Creek sediments in 1989 (U.S. Fish and Wildlife Service, 1991) was not reconfirmed. Total PCB's for all samples were below the 0.05 ppm wet weight detection limit.

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Table 4. Five minute $EC_{50}$ MICROTOX results and corresponding toxic criteria of Mud Creek sediments.

| SAMPLE | PERCENT RESPONSE | 95 PERCENT CONF INTERVAL | TOXIC CRITERIA |
|---|---|---|---|
| SRS | > 100 | N/A | Non-toxic |
| SMC1S | 18.72 | 17.25 - 20.32 | Extremely Toxic |
| SMC2S | 85.54 | 76.04 - 96.21 | Slightly Toxic |
| SMC3S | 81.65 | 66.09 - 100.86 | Slightly Toxic |
| SMC4S | 37.05 | 34.71 - 39.55 | Very Toxic |
| SMC5S | 38.25 | 34.02 - 43.01 | Very Toxic |
| SFR1S | 46.30 | 40.42 - 53.06 | Toxic |
| SFR2S | 72.18 | 64.42 - 80.87 | Moderately Toxic |

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Table 5. Percent survival of <u>Hyalella azteca</u> in Mud Creek Sediment 14-day bioassay testing.

| SEDIMENT/REPLICATE | PERCENT SURVIVAL | MEAN SURVIVAL | SIGNIFICANCE[1] |
|---|---|---|---|
| Negative Control/1 | 80 | | |
| Negative Control/2 | 90 | 83.3 | |
| Negative Control/3 | 80 | | |
| SRS/1 | 95 | | |
| SRS/2 | 95 | 96.7 | |
| SRS/3 | 100 | | |
| SMC1S/1 | 100 | | |
| SMC1S/2 | 100 | 100.0 | NS |
| SMC1S/3 | 100 | | |
| SMC2S/1 | 65 | | |
| SMC2S/2 | 100 | 88.3 | NS |
| SMC2S/3 | 100 | | |
| SMC3S/1 | 90 | | |
| SMC3S/2 | 80 | 90.0 | NS |
| SMC3S/3 | 100 | | |
| SMC4S/1 | 80 | | |
| SMC4S/2 | 80 | 83.3 | NS |
| SMC4S/3 | 90 | | |
| SMC5S/1 | 60 | | |
| SMC5S/2 | 90 | 80.0 | NS |
| SMC5S/3 | 90 | | |

[1]NS = Mean survival not significantly different from reference (SRS). ($P > 0.05$, ANOVA)

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The only organochlorine detected in Mud Creek sediments was p,p'-DDE, a degradation product of DDT. Converted dry weight levels ranged from 0.03 to 0.26 ppm and were not above any of the comparative criteria.

Converted dry weights for total PAHs ranged from 0.96 to 2.22 ppm and were all well below the established comparative criteria.

Total organic carbon for Mud Creek sediments was consistent across samples ranging from 2.3 to 7.0 percent. The reference sample contained the lowest percent TOC at 2.1 percent. Grain size characteristics were fairly uniform with generally less than 1 percent clay, 16.7 to 25.6 percent silt, and 72.7 to 82.2 percent sand.

Metals detected in Mud Creek and/or reference site sediments above screening criteria of concern were arsenic, beryllium, lead, mercury, nickel, and zinc (Table 6).

## REFUGE IMPOUNDMENT

### Sediments

Total organic carbon for Refuge impoundment sediments was consistent across samples ranging from 2.7 to 6.5 percent. The reference sample contained the lowest percent TOC at 2.1 percent. Grain size characteristics were fairly uniform with less than 1.0 percent clay, 12.5 to 38.3 percent silt and 47.8 to 69.5 percent sand.

Metals detected in the Refuge impoundment and/or reference site sediments above screening criteria of concern were arsenic, beryllium, chromium, copper, lead, mercury, nickel, and zinc (Table 7).

### Surface Water

Analyses for 19 elements were conducted with impoundment and reference site surface waters (Table 1). All but selenium and mercury were detected above the limits of detection. Of the remaining 17 elements, 8 were detected at concentrations considered toxic to aquatic organisms (arsenic, chromium, copper, iron, nickel, lead, and zinc). Table 8 depicts the samples and concentrations that exceed the criteria of USEPA (1986).

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Table 6. Elemental contaminants (ppm, dry weight) detected in Mud Creek and reference site sediments above the screening criteria.

ARSENIC

| SAMPLE | RESULT | NJDEPE ISAL | NOAA ER-L | NOAA ER-M | AET | U.S. EPA POLLUTION CLASS |
|---|---|---|---|---|---|---|
| SMC5S | 21.1 | 20.0 | 33.0 | 85.0 | 57 | heavily polluted |

BERYLLIUM

| SAMPLE | RESULT | NJDEPE ISAL | NOAA ER-L | NOAA ER-M | AET | U.S. EPA POLLUTION CLASS |
|---|---|---|---|---|---|---|
| SMC5S | 1.21 | 1.0 | N/A | N/A | N/A | N/A |
| SMC4S | 1.13 | | | | | |
| SMC3S | 1.12 | | | | | |
| SMC2S | 1.11 | | | | | |
| SMC1S | 1.39 | | | | | |
| SFR2S | 1.21 | | | | | |
| SFR1S | 1.09 | | | | | |
| SRS | 1.16 | | | | | |

MERCURY

| SAMPLE | RESULT | NJDEPE ISAL | NOAA ER-L | NOAA ER-M | AET | U.S. EPA POLLUTION CLASS |
|---|---|---|---|---|---|---|
| SMC5S | 0.38 | 1.0 | 0.15 | 1.3 | 2.1 | non polluted |
| SMC4S | 0.42 | | | | | |
| SMC3S | 0.37 | | | | | |
| SMC2S | 0.48 | | | | | |
| SMC1S | 0.44 | | | | | |
| SFR2S | 0.45 | | | | | |
| SFR1S | 0.49 | | | | | |
| SRS | 0.31 | | | | | |

NICKEL

| SAMPLE | RESULT | NJDEPE ISAL | NOAA ER-L | NOAA ER-M | AET | U.S. EPA POLLUTION CLASS |
|---|---|---|---|---|---|---|
| SMC5S | 40.2 | 100.0 | 30.0 | 50.0 | <140 | moderately polluted |
| SMC4S | 43.1 | | | | | |
| SMC3S | 34.3 | | | | | |
| SMC2S | 32.3 | | | | | |
| SMC1S | 43.0 | | | | | |
| SFR2S | 41.8 | | | | | |
| SFR1S | 42.6 | | | | | |
| SRS | 37.1 | | | | | |

LEAD

| SAMPLE | RESULT | NJDEPE ISAL | NOAA ER-L | NOAA ER-M | AET | U.S. EPA POLLUTION CLASS |
|---|---|---|---|---|---|---|
| SMC5S | 83.3 | 250.0 | 35.0 | 110.0 | 450 | heavily polluted |
| SMC4S | 76.7 | | | | | |
| SMC3S | 71.5 | | | | | |
| SMC2S | 88.3 | | | | | |
| SMC1S | 81.0 | | | | | |
| SFR2S | 108.0 | | | | | |
| SFR1S | 117.0 | | | | | |
| SRS | 58.3 | | | | | moderately polluted |

ZINC

| SAMPLE | RESULT | NJDEPE ISAL | NOAA ER-L | NOAA ER-M | AET | U.S. EPA POLLUTION CLASS |
|---|---|---|---|---|---|---|
| SMC5S | 425.0 | 350.0 | 120.0 | 270.0 | 410 | heavily polluted |
| SMC4S | 431.0 | | | | | |
| SMC3S | 274.0 | | | | | |
| SMC2S | 264.0 | | | | | |
| SMC1S | 307.0 | | | | | |
| SFR2S | 290.0 | | | | | |
| SFR1S | 346.0 | | | | | |
| SRS | 240.0 | | | | | |

Table 7. Elemental contaminants (ppm, dry weight) detected in the Refuge impoundment and reference site sediments above the screening criteria.

ARSENIC

| SAMPLE | RESULT | NJDEPE ISAL | NOAA ER-L | NOAA ER-M | AET | U.S. EPA POLLUTION CLASS |
|---|---|---|---|---|---|---|
| SMI4S | 27.6 | 20 | 33 | 85 | 57 | heavily polluted |
| SMI3S | 24.3 | | | | | heavily polluted |
| SMI2S | 39.5 | | | | | heavily polluted |

BERYLLIUM

| SAMPLE | RESULT | NJDEPE ISAL | NOAA ER-L | NOAA ER-M | AET | U.S. EPA POLLUTION CLASS |
|---|---|---|---|---|---|---|
| SMI2S | 1.38 | 1.0 | N/A | N/A | N/A | N/A |
| SMI1S | 1.37 | | | | | |
| SRS | 1.16 | | | | | |

CHROMIUM

| SAMPLE | RESULT | NJDEPE ISAL | NOAA ER-L | NOAA ER-M | AET | U.S. EPA POLLUTION CLASS |
|---|---|---|---|---|---|---|
| SMI4S | 103.0 | 100 | 80 | 145 | 260 | heavily polluted |
| SMI2S | 89.2 | | | | | heavily polluted |

COPPER

| SAMPLE | RESULT | NJDEPE ISAL | NOAA ER-L | NOAA ER-M | AET | U.S. EPA POLLUTION CLASS |
|---|---|---|---|---|---|---|
| SMI2S | 71.8 | 170 | 70 | 390 | 390 | heavily polluted |

MERCURY

| SAMPLE | RESULT | NJDEPE ISAL | NOAA ER-L | NOAA ER-M | AET | U.S. EPA POLLUTION CLASS |
|---|---|---|---|---|---|---|
| SMI5S | 0.30 | 1.0 | 0.15 | 1.3 | 2.1 | non polluted |
| SMI4S | 1.18 | | | | | heavily polluted |
| SMI3S | 0.77 | | | | | non polluted |
| SMI2S | 0.72 | | | | | non polluted |
| SMI1S | 0.39 | | | | | non polluted |
| SRS | 0.31 | | | | | non polluted |

NICKEL

| SAMPLE | RESULT | NJDEPE ISAL | NOAA ER-L | NOAA ER-M | AET | U.S. EPA POLLUTION CLASS |
|---|---|---|---|---|---|---|
| SMI2S | 40.5 | 100.0 | 30.0 | 50.0 | <140 | moderately polluted |
| SMI1S | 42.4 | | | | | moderately polluted |
| SRS | 37.1 | | | | | moderately polluted |

LEAD

| SAMPLE | RESULT | NJDEPE ISAL | NOAA ER-L | NOAA ER-M | AET | U.S. EPA POLLUTION CLASS |
|---|---|---|---|---|---|---|
| SMI5S | 54.2 | 250.0 | 35.0 | 110.0 | 450 | moderately polluted |
| SMI4S | 156.0 | | | | | heavily polluted |
| SMI3S | 108.0 | | | | | heavily polluted |
| SMI2S | 129.0 | | | | | heavily polluted |
| SMI1S | 81.5 | | | | | heavily polluted |
| SRS | 58.3 | | | | | moderately polluted |

ZINC

| SAMPLE | RESULT | NJDEPE ISAL | NOAA ER-L | NOAA ER-M | AET | EPA POLLUTION CLASS |
|---|---|---|---|---|---|---|
| SMI5S | 158.0 | 350.0 | 120.0 | 270.0 | 410 | moderately polluted |
| SMI4S | 160.0 | | | | | moderately polluted |
| SMI3S | 382.0 | | | | | heavily polluted |
| SMI2S | 811.0 | | | | | heavily polluted |
| SMI1S | 302.0 | | | | | heavily polluted |
| SRS | 240.0 | | | | | heavily polluted |

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Table 8. Surface water samples (ppm) from the Refuge impoundment that exceed USEPA acute and/or chronic criteria.

| | | | U.S. EPA'S MOST SENSITIVE CRITERIA OR LOWEST EFFECT LEVEL | |
|---|---|---|---|---|
| SAMPLE ID | ELEMENT | SAMPLE CONC. | ACUTE | CHRONIC |
| SRW (Reference) | Copper | 0.007 | 0.0029 | 0.0029 |
| | Iron | 1.37 | ----- | 1.000 |
| SMI1W | Copper | 0.013 | 0.0029 | 0.0029 |
| | Iron | 8.79 | ----- | 1.000 |
| | Lead | 0.0066 | 0.082 | 0.0032 |
| SMI2W | Chromium | 0.034 | 0.016 | 0.011 |
| | Copper | 0.024 | 0.0029 | 0.0029 |
| | Iron | 17.8 | ----- | 1.000 |
| | Lead | 0.0357 | 0.082 | 0.0032 |
| | Nickel | 0.016 | 0.075 | 0.0083 |
| | Zinc | 0.211 | 0.095 | 0.086 |
| SMI3W | Arsenic | 0.062 | 0.85 | 0.048 |
| | Cadmium | 0.002 | 0.0039 | 0.0011 |
| | Chromium | 0.099 | 0.016 | 0.011 |
| | Copper | 0.085 | 0.0029 | 0.0029 |
| | Iron | 88.2 | ----- | 1.000 |
| | Lead | 0.141 | 0.082 | 0.0032 |
| | Nickel | 0.046 | 0.075 | 0.0083 |
| | Zinc | 0.744 | 0.095 | 0.086 |

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## DISCUSSION

### MUD CREEK

Beryllium, mercury, and nickel were detected consistently slightly above a single criterion (NJDEPE ISAL of 1.0 ppm for beryllium, NOAA's ER-L of 0.15 ppm for mercury, and NOAA's ER-L of 30 ppm for nickel) in all samples and the reference site; therefore, they appear ubiquitous and cannot be attributed to the Killcohook dredge disposal site.

Although the reference site lead and zinc levels exceeded the NOAA ER-L value, these metal concentrations in all Mud Creek sediments were higher than the reference site concentration. These data suggest that elevated concentrations of lead and zinc found in Mud Creek may be attributed to the Killcohook outfall. However, since the highest levels of lead and zinc in this study were found in the refuge impoundment (discussed below), and not directly influenced by the Killcohook outfall, evidence exists that the elevated levels found in Mud Creek may be from some other unknown source in the general area. A potential source may be contaminated groundwater surface discharge to the marshes bordering Mud Creek and Fort Mott Road. Review of drinking water well data and evaluation of subsurface hydrology may reveal potential sources. Lead levels were highest in the two most downgradient samples taken near the Freas property dumpsite, indicating that this site may be a source of lead contamination.

The single arsenic detection above the NJDEPE ISAL of 20.0 ppm detected in Mud Creek adjacent to the outfall (SMC5s, 21.1 ppm), cannot be solely attributed to the Killcohook outfall. Concentrations nearly double that value were found in the refuge impoundment. Additionally, since this value is below NOAA's ER-L of 33.0 ppm, anticipated adverse effects to aquatic organisms appear minimal.

The MICROTOX results and various exceedences of NOAA's ER-L and ER-M values in Mud Creek sediments clearly indicate the potential for acute and chronic adverse effects to aquatic fauna. The corresponding lack of acute adverse effects observed in the laboratory *Hyalella azteca* bioassay work may be explained. Many parameters can directly affect both the toxicity and potential exposure of organisms to contaminated sediment in either a natural or laboratory setting. Some examples include water chemical parameters, contaminant bioavailability, contaminant mode of action, and organism sensitivity and behavior. Several other aspects may affect the results of laboratory-based studies including the physical laboratory conditions, duration of study, effects endpoint, sample size, number of replications, and method of statistical analyses. Therefore, although no statistically significant decrease in survival of *Hyalella azteca* was observed in Mud Creek sediments when compared to the reference site, data suggest that other aquatic organisms occupying these sediments may still be at risk from contamination. Data are sufficient to conclude that no gross contamination is evident in Mud Creek; however, sampling within the Kilcohook dredge disposal site and chronic effects data are needed to determine if operational changes are warranted.

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REFUGE IMPOUNDMENT

In general, the extent of contamination in the refuge impoundment was greater than that of Mud Creek sediments. It should be noted that sampling of the refuge impoundment occurred during very dry conditions, and the impoundment was well below full capacity. As such, sampling reflected a worst case scenario as hydrophilic contaminants were concentrated in a much smaller area than usual. Nonetheless, several analytes were found to exceed screening criteria. As with the Mud Creek sediments, beryllium was detected slightly above the NJDEPE ISAL of 1.0 ppm for two impoundment sites and the reference site. Therefore, beryllium levels were not considered elevated in the impoundment.

Elevated arsenic concentrations were detected in three of the impoundment samples, with one value exceeding the NOAA ER-L. Therefore, some adverse effects to benthic organisms from arsenic may be occurring in the impoundment.

Chromium and mercury levels in sample SMI4S exceeded the reference site, NJDEPE ISAL, and NOAA ER-L values. As such, current contamination can not be background-related and adverse effects from these contaminants are most likely occurring.

The previously confirmed zinc level of 2,980 ppm in 1989 was not reconfirmed, although the highest level detected in this study (811 ppm) still exceeded the NJDEPE ISAL, NOAA ER-M, and USEPA's AET value. All values exceeded the NOAA ER-L, and three of the five samples exceeded the ER-M value. These results confirm the consistent elevated levels of zinc, which are a serious concern for benthic organisms (Olsen, 1984).

It was indicated in the Service's previous report that the history of waterfowl hunting in this area may implicate lead shot as a source of lead contamination (U.S. Fish and Wildlife Service, 1989). As hypothesized in the 1989 report, areas of greater lead enrichment were detected in this current sampling effort, with a maximum concentration of 159 ppm. Lead poisoning of waterfowl from ingestion of lead shot has been documented in the region (Roscoe et al., 1989); however, these researchers hypothesized that ducks were ingesting newly deposited lead pellets from a skeet range while feeding. The researchers further suggested that the altered appearance of older, oxidized, shot, combined with the reduced visibility from settling or siltation, resulted in no further waterfowl die-offs the following year. The aquatic and benthic organisms present in the impoundment are believed to be at greatest risk from current lead concentrations. Lead is very toxic to aquatic organisms, especially fish and algae (Leland and Kuwabara, 1985). Lead tends to bioaccumulate in mussels and clams (Schmitt et al., 1987), and benthic fish may accumulate lead directly from the sediments (Munawar et al., 1984). Synergistic effects of lead and cadmium and additive effects of lead, copper, zinc, cadmium, and mercury have been documented for aquatic biota (Demayo et al., 1984).

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Results from the 1989 study did not show alarming concentrations of lead or zinc in mummichog tissues collected from the refuge impoundment; however, the area of sampling was limited to a small inlet leading into the northern edge of the impoundment. This drainage ditch is upgradient from the current known areas of contamination, and may even be isolated from the impoundment during low water conditions. Further chemical analyses of biota in and surrounding the refuge impoundment would help to better characterize potential adverse effects from lead and zinc contamination.

The reference site surface water contained elevated concentrations of iron and copper. Although these values were in excess of the USEPA (1986) criteria for adverse effects, the impoundment surface water maximum concentrations were nearly 1 and 2 orders of magnitude higher for copper and iron, respectively. Therefore, the contaminants of concern observed in the refuge impoundment surface waters (all of the above), can not be attributed to background metal concentration. As illustrated, levels exceed chronic effect criteria for all of the above metals. Furthermore, acute criteria are exceeded for all but arsenic, cadmium, nickel, and iron (no acute criteria exists for iron). Many of the above water quality criteria are derived from data collected under laboratory conditions and are very dependent upon parameters such as pH, DO, temperature, water hardness, and salinity. Therefore, direct comparison to actual conditions at the refuge impoundment should be made with caution. However, this comparison does show that the above metals can potentially impact a variety of aquatic organisms in the surface water of the refuge impoundment. These impacts can include mortality, decreased survival, and growth and developmental problems. Dilution factors should be considered before making definitive statements regarding overall water quality of the entire impoundment and potential downgradient surface water impacts in outflows.

Elevated surface water and sediment zinc in the Delaware estuary have been reported by Hochreiter (1982), Delaware Department of Natural Resources and Environmental Control (1987), and Ellis et al. (1980). This phenomenon requires further investigation, particularly at the refuge impoundment where elevated sediment lead and zinc are most likely affecting the aquatic and benthic community. Since immature shore birds and waterfowl feed extensively on aquatic invertebrates, potential exists for a severe depletion of food sources from lead and zinc present in the refuge impoundment. Furthermore, contaminant levels suggest that chronic effects to a variety of aquatic and terrestrial organisms may occur through bioaccumulation of these heavy metals.

## CONCLUSIONS/RECOMMENDATIONS

### MUD CREEK

Zinc levels were the highest at the two sampling stations nearest the outfall from the dredge disposal site and were clearly above reference or background concentrations. Data suggest that the elevated sediment levels of lead and zinc in Mud Creek may be attributed to the Killcohook dredge disposal site.

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Although acute toxicity bioassay testing with Mud Creek sediments showed no significant decreased survival in Hyalella azteca, definitive statements regarding the range of possible adverse effects to other aquatic organisms can not be made. Determination of gradient-related contaminant influences (i.e., samples analyzed within the Kilcohook dredge disposal site) and chronic effects data should be generated to determine if operational changes at the Killcohook dredge disposal site are warranted. Since the Service has expressed interest in better managing water levels on dredge material disposal sites for the benefit of waterfowl, it is imperative to be certain that these disposal areas are not adversely affecting aquatic and terrestrial fauna. Lead levels were highest in the two most downgradient samples taken near the Freas property dumpsite, indicating that this site may be a source of lead contamination.

REFUGE IMPOUNDMENT

Surface water concentrations exceed acute and / or chronic effect criteria for eight metals (arsenic, chromium, cadmium, copper, iron, nickel, lead, and zinc). These data suggest that the above metals can potentially impact a variety of aquatic organisms in the surface water of the refuge impoundment. Several metal concentrations in sediments are considered elevated (arsenic, chromium, mercury, lead, and zinc), which implies that adverse effects to benthic fauna are occurring. Future bioassays and benthic monitoring would help elucidate adverse effects suggested by the elevated concentrations of metals observed. Furthermore, long-term studies may be helpful in determining potential bioaccumulation and chronic effects from lead and zinc contamination in the Refuge impoundment. Therefore, it is recommended that prior to enhancement of waterfowl habitat around the impoundment, studies be conducted to ensure that: 1) adequate benthic invertebrate populations exist to support recruiting avian populations; and, 2) the invertebrate and vegetative food base within and surrounding the impoundment are not posing risks to consumers. Futhermore, the results of additional tissue analyses of fish known to occupy the refuge impoundment would better define potential risk to consumers. Such data would certainly aid decisions regarding public access and potential future recreational activities in the refuge impoundment.

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